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SUMMERTIME RAINFALL REGIMES IN SOUTHERN ALABAMA AND NORTHWEST FLORIDA AS DEDUCED FROM WIND-STRATIFIED RADAR DATA: PRELIMINARY STUDY 1976

Daniel L. Smith and Kevin Henderson, WSFO, Birmingham, Alabama

Scientific Services Division
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I. INTRODUCTION

This preliminary analysis is a further examination of the summertime rainfall regimes of Southern Alabama and Northwest Florida (see Smith, 1977; hereafter referred to as A). Figures are presented which show, for various prevailing wind directions, the spacial and temporal frequency distribution of radar echoes in the subject area. While the figures are based on data from only a single summer there is supporting evidence which indicates that the patterns depicted are more-or-less representative of stable regimes.

Earlier analysis (A) has shown considerable variation on a day-to-day basis in rainfall (radar echo) coverage in National Weather Service (NWS) forecast zones in Southern Alabama and the Florida Panhandle (Fig. 1). It has long been established that, at least in coastal areas*, the prevailing flow has a marked effect on the areal and temporal distribution of summertime showers. Very near the coast (within about 50 miles) the interaction and subsequent influence of prevailing flow and land/sea breezes is especially pronounced. A growing body of literature establishes these facts both observationally (Moore, 1963; Frank et al, 1967; Smith, 1970) and with increasingly elaborate numerical models (Estoque, 1962; McPherson, 1970; Pielke, 1974).

Of particular interest for the present investigation are echo frequency distributions shown by Smith (1970) for a portion of Northwest Florida bordering on and including part of the present study area. Based on three years of radar data from Apalachicola, the characteristics of the stratified rainfall regimes shown in that study are unmistakably similar to those which will be shown below. By way of introduction to that work it was noted that

> Among the obvious advantages in the use of radar in studying the time and space distribution of convective showers are the observations of echo-producing activity offshore as well as the continuous distribution of echo activity (showers) over land. Such observations are not otherwise available... Care must be taken, however, in correlating an echo observation with a simultaneous measured rainfall occurrence. Earlier studies...have shown that factors such as beam width (resolution), range effects ("over-shooting") and rainfall intensity contribute to a correlation coefficient significantly less than 1.0.

The caution is especially applicable in consideration of the preliminary nature of these results.

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*Within about 100 miles of the coast.

2. DATA

Radar data were extracted from hand-drawn hourly overlays prepared by the staff of the NWS Pensacola, Florida, WSR-57 site. A gridded overlay, Fig. 2, consisting of squares roughly 20 nmi on a side was used to digitize the data. The sample period extended from June 1 until August 31, 1976. At three-hour intervals, with intermediate times chosen as required, echo frequency analyses were made. Prior to preparation of the frequency analyses, however, each day was classified according to the prevailing low-level wind flow, as determined by averaging the Apalachicola 1200GMT wind at 1000-, 950-, 900- and 850 mb. The 1200GMT wind was used to "type" the 12-hour periods prior to and subsequent to the wind observation. Other schemes can be easily conceived for typing the wind regime -- some probably better than that used -- however, the system chosen was the only one which presented itself at the time this study was made. Similar to that used by Smith (1970), it is considered to be adequate for revealing characteristic echo patterns. The wind, and thus the day, was categorized by quadrants as northerly, easterly, southerly or westerly. If the average speed was less than five knots the classification was "light and variable".

Our concern in this study is with characteristic patterns in summertime rainfall; presumably convection dominates and the influence of synoptic scale features is at a minimum. Summer is also the season when land/sea breeze and prevailing flow interactions are at a maximum. The summer of 1976 was below normal in terms of tropical activity in the Gulf (and along the Gulf Coast) but, as shown in A, rain frequency was normal in the study area. The latter fact lends further credence to the derived echo frequency analyses.

3. ECHO FREQUENCIES

The Appendix contains reproductions of working figures derived for use at the Birmingham Weather Service Forecast Office (WSFO). Each figure shows the diurnal variation of echo frequency for a specific wind regime. For comparison, the Appendix also contains a set of figures from the earlier analysis by Smith. Characteristic patterns of each regime are briefly described below.

Southerly Days

The predominant feature of this wind regime is the high overall echo frequency, compared with other regimes. This is related, of course, to the generally high moisture content of the Gulf air mass.

At about 2AM (all times CDT), the time of minimum activity, there are only spotty weak maxima offshore (frequencies <20%). Before sunrise frequencies increase considerably as the land breeze becomes well established and opposes the prevailing flow -- resulting in convergence offshore. Why echo frequencies are highest south of Mobile and Pensacola is not clear. Note in the figure from the earlier study, at about the same time of day, that echoes are most frequent about the same distance offshore.

By 8:35AM relatively high frequencies have begun to shift onshore. This is too early to be the result of a seabreeze and probably reflects simply the northward advection of earlier offshore activity. It is possible that the location of maxima northeast of Pensacola and south of Mobile reflect some single event which contaminates the limited data sample. By 11:35AM there is no doubt that the seabreeze effect is being seen -- and noticably far inland as echo frequencies increase considerably. Note the high frequency on the western side of Mobile Bay (possibly over the Bay). McPherson (1970) showed that bays along the upper Texas coast produced similar effects. Further investigation of this small scale feature, with the cooperation of the Weather Service Office at Mobile, might prove interesting. If our prevailing southerly flow was, in fact, southwesterly this might explain the tendency for higher frequencies along the western edge of the Bay.

As early as 11:35AM the frequency maxima are well inland -- over Florida zones 1 and 3 (Fig. 1). Through the early afternoon the maxima show a northward progression. The southerly regime is one of morning showers along the coast and afternoon showers inland. Having aided in the rapid generation of onshore maxima before noon, it is doubtful that the seabreeze can be invoked to explain propagation of showers northward beyond zones 1 and 3 later in the afternoon. Once convection becomes widespread the thermal forcing of the seabreeze is destroyed. The steady northward progression of high frequencies results from diurnal formation and propagation of showers in the moist, unstable southerly flow of this regime. Note that high frequencies extend well into southern Alabama. By 5:35PM frequencies have begun to decrease as extensive convection "self-destructs" due to reduction of thermal forcing. A similar effect can be seen during the afternoon in the figures from the earlier study with Apalachicola data.

The pronounced afternoon maximum which the earlier study revealed over the Apalachicola "subpeninsula" is evident, but muted, in the Pensacola echo frequency analyses. Range effects may be to blame. The maximum arises from confluence of the seabreezes along the coasts which extend northeast and northwest from Apalachicola (see the "light and variable" figures from the Apalachicola study).

After 5:35PM, and by 8:35PM, there is a total "collapse" of activity with only a weak maximum persisting near and north of Mobile. This maximum may be related to the predawn offshore maximum and be only a transient feature of no statistical significance. It is possible, however, that it represents a very real effect -- residual shower activity over the rivers and marshes extending northward from Mobile Bay. Again, further study of this possible local effect might prove rewarding.

By 11:35PM almost all activity, in the mean, has ended over land and the offshore maximum near Mobile can be seen. It may be that an offshore "hot spot" exists in that area of seemingly preferred development. Infrared satellite imagery might detect such a feature.

Light and Variable Days

This frequent regime is discussed next because of its contrast with the southerly regime. As with southerly days the overall minimum of activity occurs in the hours after midnight. Until about 8:00AM the weak offshore maxima are similar to southerly days except that there is no indication of the "hot spot" south of Mobile -- suggesting that such does not actually exist, at least as a stable feature. The activity offshore at 8:35AM is probably too far offshore to reflect the relatively weak land breeze. It is more likely an effect of warmer offshore water.

Basically, the light and variable regime represents days as moist and unstable as those with southerly flow; this is reflected by similar maximum echo frequencies. The location of echoes, however, becomes strikingly different after daytime heating begins. Notice the great difference between echo frequency distributions at 11:35AM for these two wind regimes. On light and variable days the nocturnal showers have dissipated offshore but heating of the land has not yet induced showers. At the same time, seabreeze-induced showers are (in the mean) well underway on southerly flow days.

There is a drastic one-hour change between 11:35AM and 12:35PM under the light and variable regime: high echo frequencies develop all along the coast. There is even a suggestion of a relative minimum between Panama City and Apalachicola induced possibly by the slightly concave coastline. The coastal maxima persist nearly all afternoon. Notice that until 5:35PM the coastal Florida zones, 2 and 4, have decidedly higher echo frequencies than the inland zones. In marked contrast to the southerly regime the Alabama and inland Florida zones show echo frequencies no greater than 20 to 30%. Apparently when the prevailing flow is light and variable the seabreeze penetrates inland no farther than the coastal zones.

Again, notice the rapid decrease in echo frequencies between 5:35 and 8:35PM. As with southerly days a relative maximum persists beyond 8:35PM northeast of Mobile, lending support to the idea that this is a real feature.

Northerly Days

The significance of the frequency analyses for this regime is somewhat doubtful. Northerly winds are not uncommon in the study area in the summer (although too few such days occurred during the Apalachicola study to even form a regime) but it is felt they represent days with significant synoptic scale contamination of the typical summer rainfall patterns. Thus, the echo frequency patterns presented in the Appendix are somewhat noisy.

For northerly days the frequency distributions are similar to the light and variable days although overall maxima are somewhat less -- to be expected, perhaps, because of the drier northerly air mass. There is a minimum in activity between midnight and dawn. Even the early morning offshore maxima are absent. This should be expected since, superimposed on the landbreeze, the northerly prevailing flow induces divergence offshore.

We cannot fully analyze the interaction of the prevailing flow and the seabreeze from echo frequency analyses alone but there is a strong tendency to conclude from the 12:35PM frequency distribution that in the mean a northerly flow retards the onset of the seabreeze until after noon. Compare the significantly higher frequencies at 12:35PM when the prevailing flow is light and variable. By 1:35PM, and for the remainder of the afternoon, northerly and light and variable regimes exhibit similar frequency distributions. While northerly winds seem to hold higher frequencies near the coast there is considerable "noise", with maxima occurring well north in southern Alabama.

The usual diurnal effect is seen with frequencies decreasing rapidly after 5:35PM. Interestingly, as late as 8:35PM frequencies remain around 20-25% over the Panhandle and there is again a tendency for a maximum near and northeast of Mobile.

Westerly Days

Because the coastline in the study area lacks large and well-defined irregularities such as the subpeninsula extending north of Apalachicola, classical seabreeze/prevailing flow interactions are difficult to identify with easterly and westerly prevailing winds. These regimes, with flow basically parallel to the coast, result in quite different frequency patterns. Each exhibits characteristics of both moist southerly flow and the light and variable regime.

Under the westerly regime overnight frequencies are very low. By 5:35PM, however, and continuing through the morning hours, a significant offshore maximum appears -- a larger area of relatively high echo frequencies than is seen under any other regime. Westerly winds (perhaps more nearly southwesterly in the mean) arrive in the study area after a considerable overwater trajectory. It is not surprising that the morning activity offshore closely resembles that of southerly days.

The figures from the earlier Apalachicola study clearly show patterns of echo formation along the windward coast before dawn (prevailing flow opposes the landbreeze) and echo formation along the leeward coast late in the morning (prevailing flow opposes the seabreeze). The Pensacola data do not reveal these features under the westerly regime. Rather, sometime shortly after noon high echo frequencies appear onshore -- with echoes more-or-less equally likely all along the coast. As with light and variable winds, echoes do not penetrate very far inland.

Surprisingly, there is a drastic decrease in echo frequencies between 2:35PM and 5:35PM. Such a sudden change, so early, is not seen under any other wind regime and its cause is somewhat of a mystery. It is possible that the echoes which produce the high frequencies east of Pensacola are merely advected eastward, beyond range of our figures, while further development is retarded in those areas where showers previously formed. Under light and variable wind conditions showers persist in the vicinity of Pensacola at 5:35PM while there is only a hint of such activity under the westerly regime. Perhaps showers in a light and variable regime are significantly different, and more steady-state, than showers or thunderstorms which form under stronger prevailing winds.

Easterly Days

In the mean, easterly prevailing winds represent the driest regime over the study area -- at least the sample data are characterized by the lowest overall echo frequencies. The general suppression of echo activity probably results from the anticyclonic circulation which exists in the mean over the study area when easterly winds prevail.

As with westerly prevailing flow, significant onshore echo activity does not begin with easterly winds until after noon. Notice, however, between 2:35 and 5:35PM a tendency for high echo frequencies along the leeward coast which extends northwestward from Apalachicola. This was shown in the earlier radar study to be a preferred area for shower development under similar conditions. Echo activity is more persistent in this area when the winds are easterly than when they are westerly. All-in-all, however, echo frequencies are quite low over the study area throughout the day.

The relatively high frequencies northeast of Mobile in the later afternoon and early evening are, again, not fully understood. A comparison of echo frequency analyses at 8:35PM for each regime shows a similar feature.

4. CONCLUSION

The analyses presented were based on radar data from a single summer. It may be argued that such a sample is insufficient for meaningful analysis, but again these results are identified as being preliminary. It was considered that sufficient corroborating data exist -- both theoretical and observational -- to warrant a close look at even this single summer season. Additional observations are being collected which will be incorporated in future analyses.

Aside from errors which crept into the analyses by way of the large grid and hand-digitizing procedure, not every echo the radar sees results in measurable rain at the ground -- and vice versa. Even as more sophisticated techniques are being developed to make the radar an accurate raingage, it is increasingly obvious that significant problems remain to be overcome. Radar is still, however, the most practical means of determining the spacial distribution of rainfall over large areas in real time -- as such it yields an excellent approximation even through crude procedures such as employed here. If better techniques are available they should be put to immediate use (and published).

The patterns presented of spacial and temporal distribution of summertime rainfall over southern Alabama and Northwest Florida appear, in general, to be both realistic and stable in the mean. It is hoped that the figures will find practical application in day-to-day forecast procedures.

NOTE: Kevin Henderson, a high school junior, was a student aide at the WSFO, Birmingham, during the school year 1976-1977.

5. REFERENCES

Estoque, M.A., 1962: The seabreeze as a function of the prevailing synoptic situation. J. Meteor., 19, 244-250.

Frank, N.L., P.L. Moore, and G.E. Fisher, 1967: Summer shower distribution over the Florida peninsula as deduced from digitized radar data. J. Appl. Meteor., 6, 309-316.

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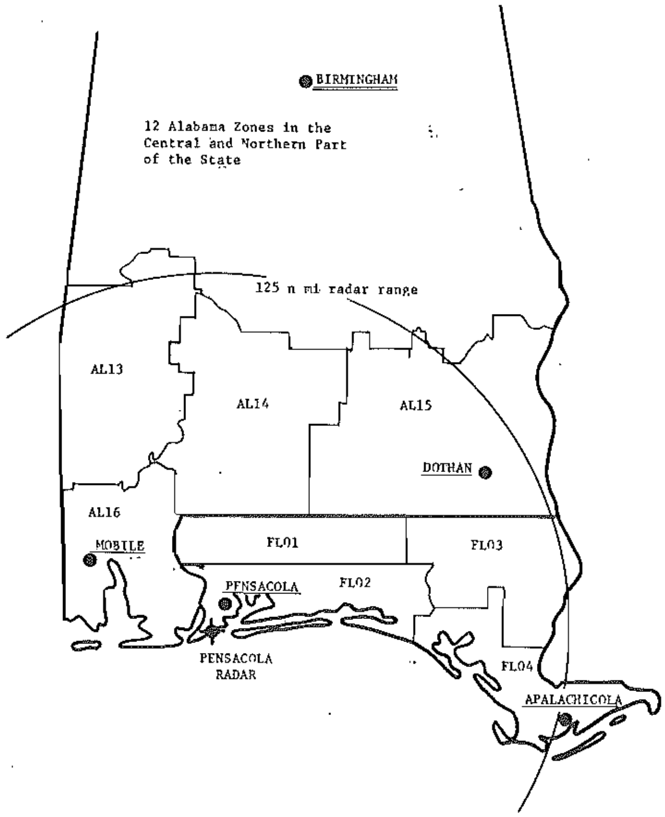


Figure 1. Birmingham WSFO forecast zones, showing their location relative to the Pensacola radar.

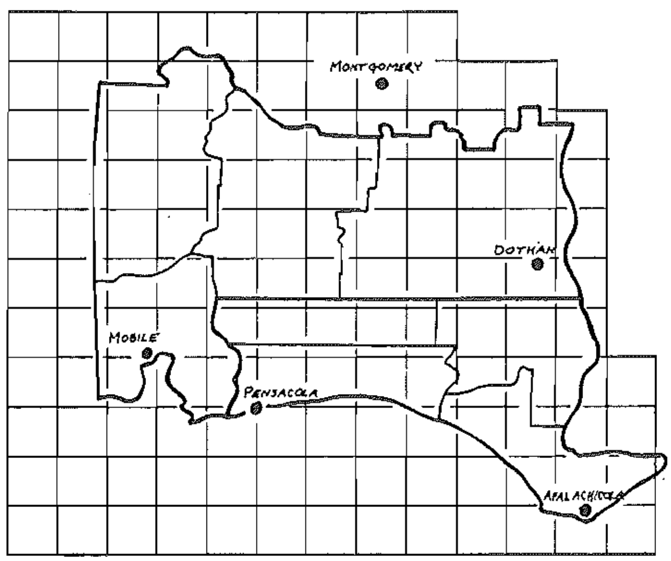


Figure 2. Gridded overlay used to digitize the Pensacola radar data. Grid squares are roughly 20 nmi on a side.

APPENDIX

Figures show the frequence of occurrence of radar echoes at various times of the day. Hand-drawn overlays were digitized using a grid of roughly 20 nmi squares. Data were stratified according to the prevailing wind regime with the following breakdown during the study period (summer of 1976):

Southerly....................18 days

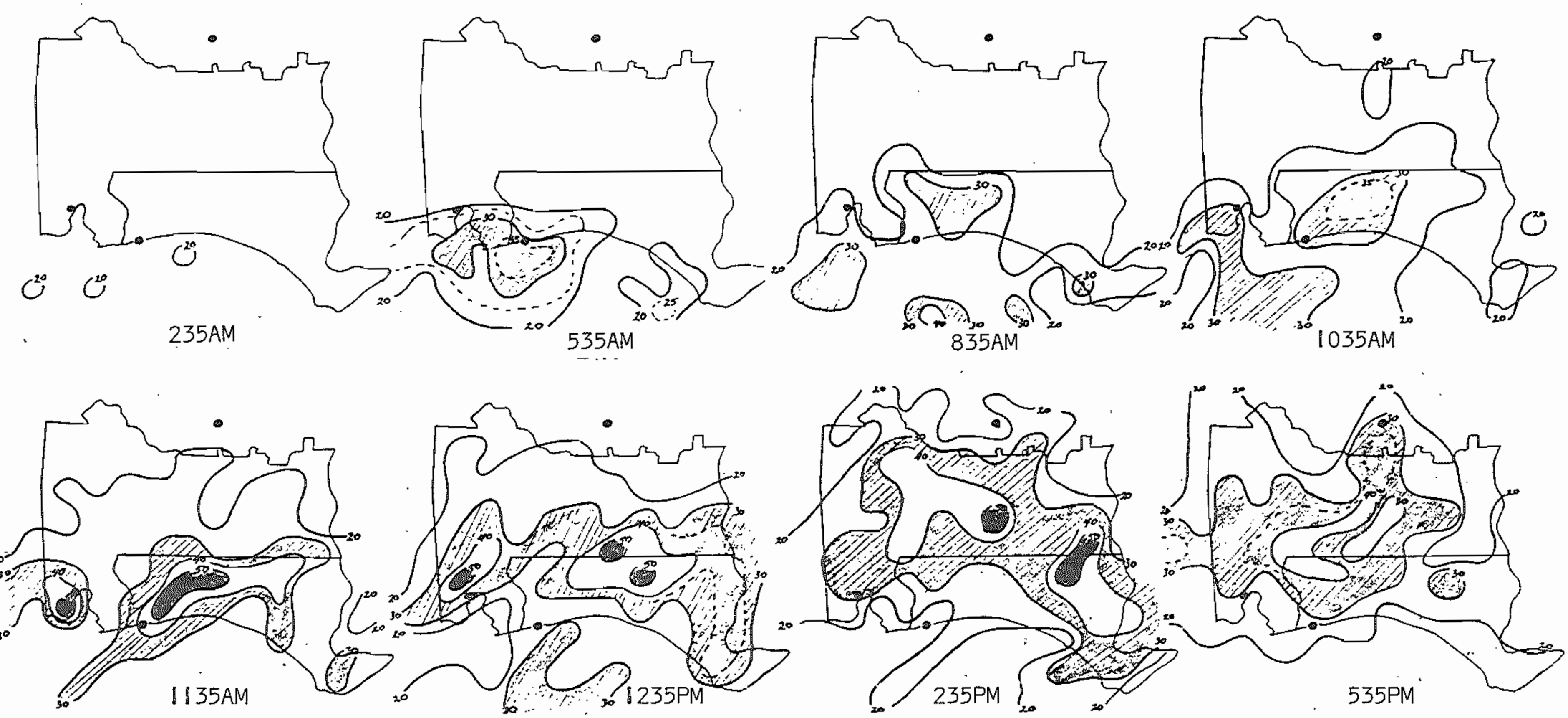
Light and Variable...........14 days

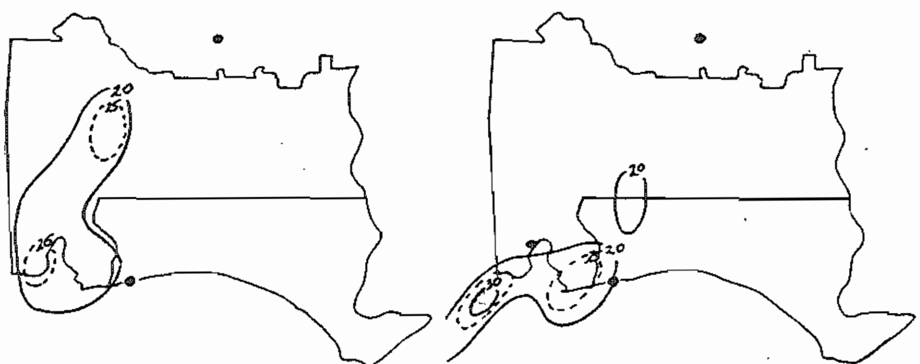
Northerly....................14 days

Easterly.....................15 days

Westerly.....................31 days

Also shown for comparison are echo frequencies from a study by Smith (1970) which utilized radar data from Apalachicola for a period of three summers.

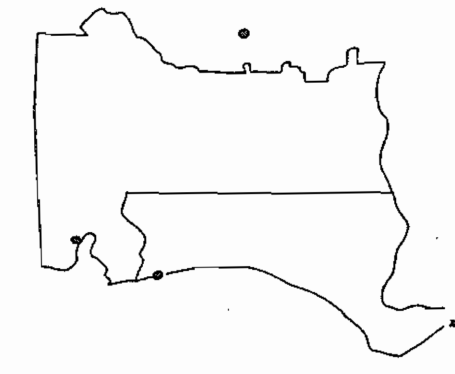




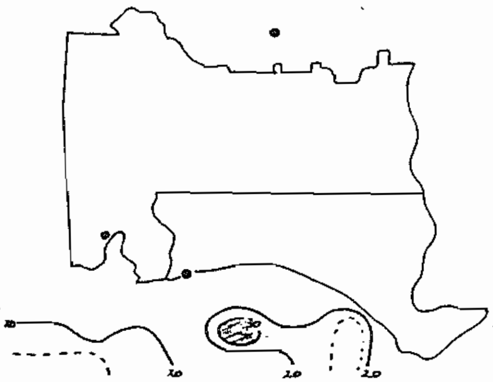
ECHO FREQUENCY:
SOUTHERLY DAYS
All times CDT.

AVG AREAL COVERAGE (%)

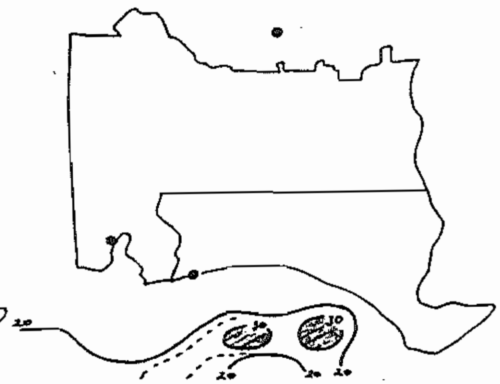
	Zone	Day (7A-7P)	Night (7P-7A)
FLA	1	51	24
	2	44	24
	3	45	14
	4	31	15
ALA	13	36	19
	14	49	25
	15	40	15
	16	46	35



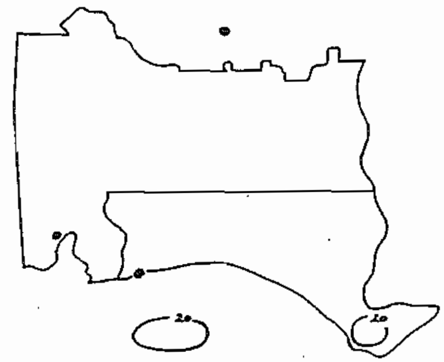
235AM



535AM

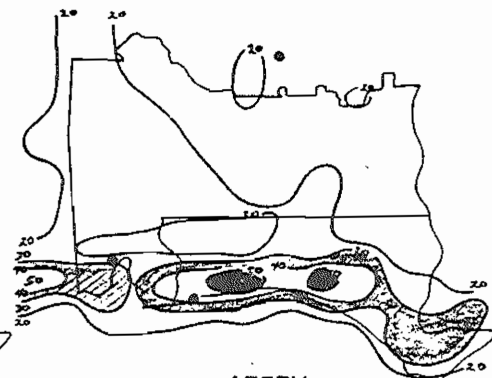


835AM

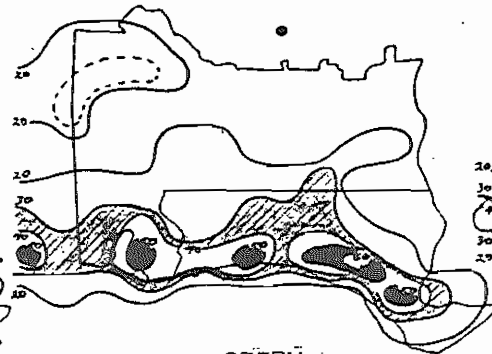


1135AM

1235PM



135PM



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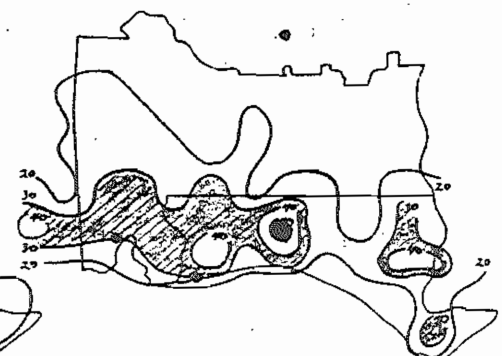

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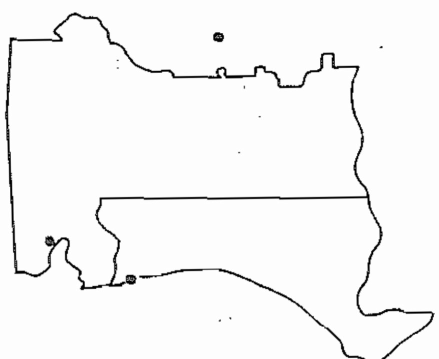
835PM

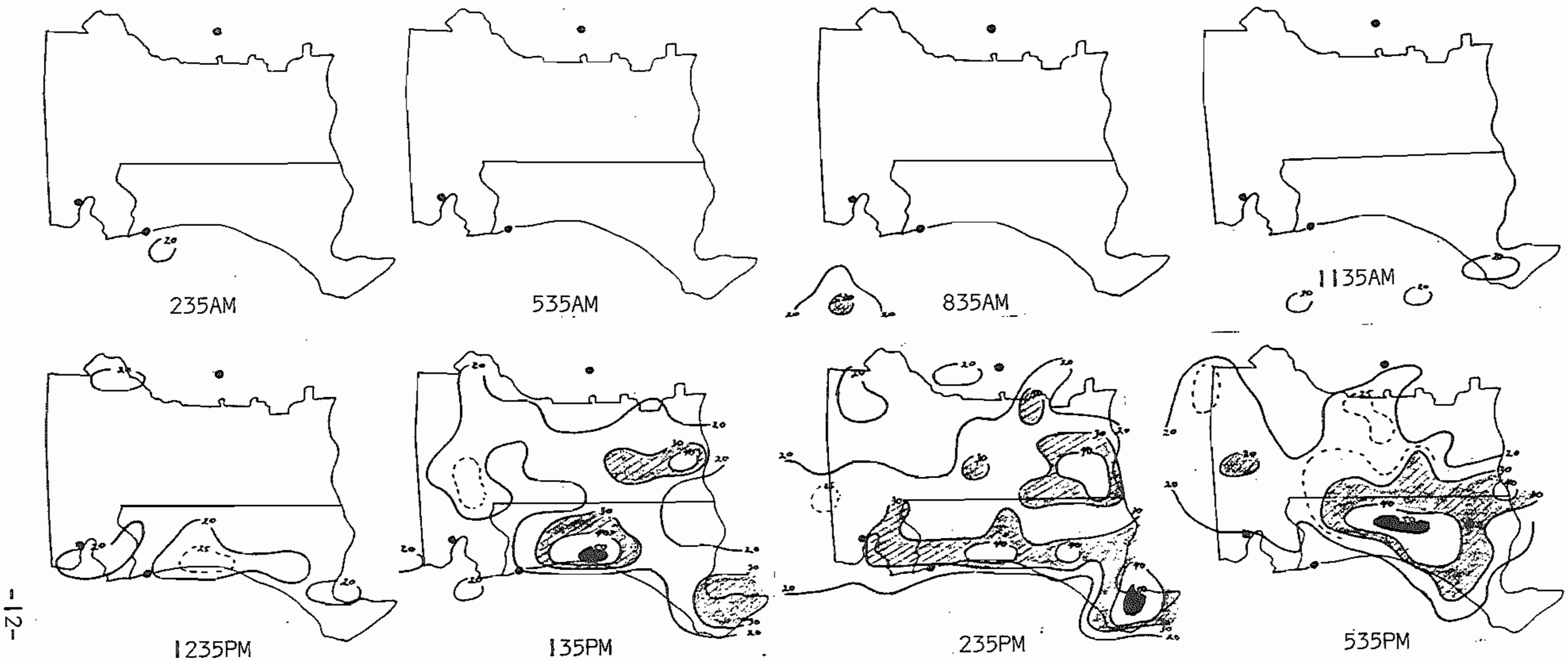


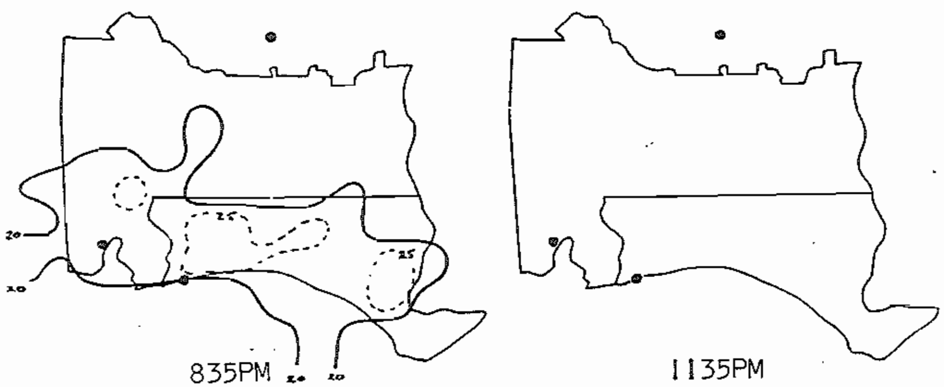
1135PM

ECHO FREQUENCY:
LIGHT & VARIABLE DAYS
All times CDT.

AVG AREAL COVERAGE (%)

	Zone	Day (7A-7P)	Night (7P-7A)
FLA	1	26	4
	2	36	3
	3	25	3
	4	29	1
ALA	13	17	7
	14	14	11
	15	9	5
	16	34	4

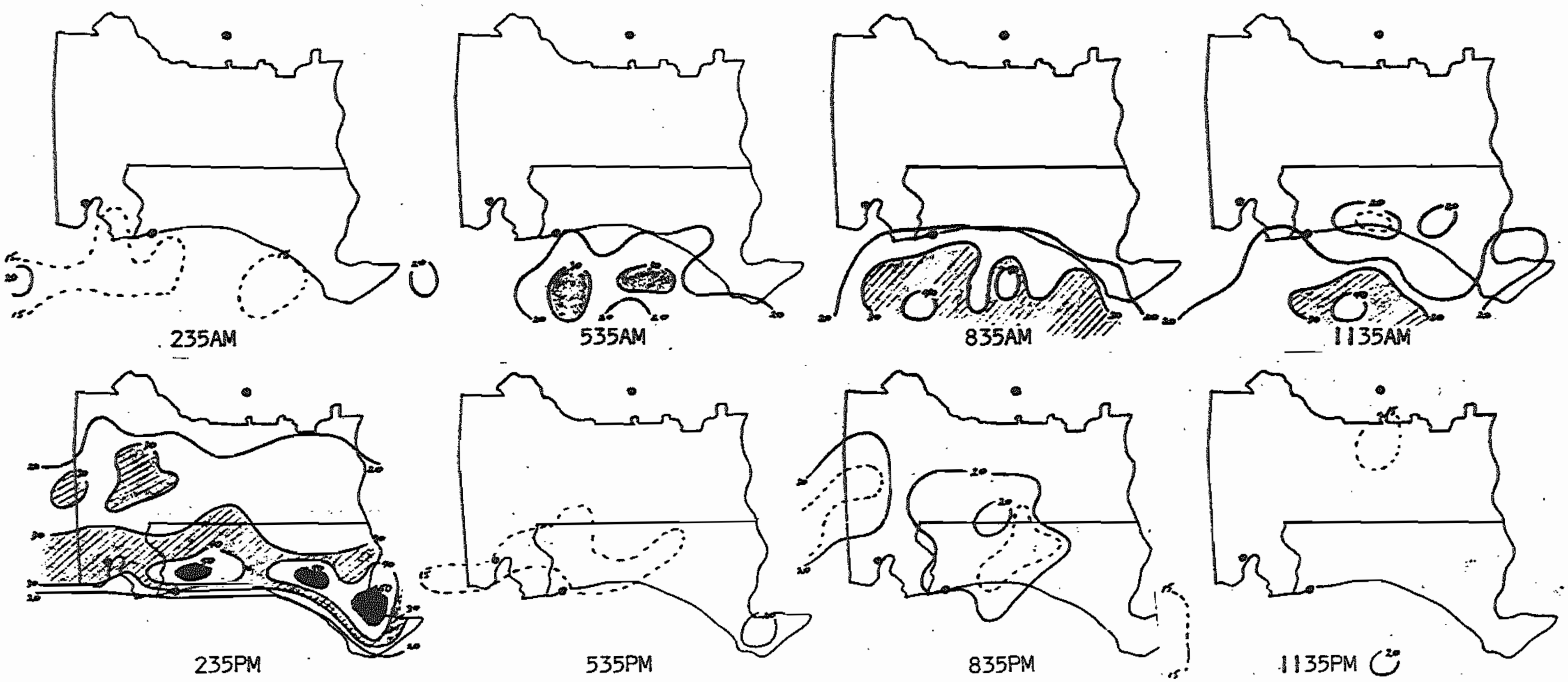




ECHO FREQUENCY
NORTHERLY DAYS
All times CDT.

AVG AREAL COVERAGE (%)

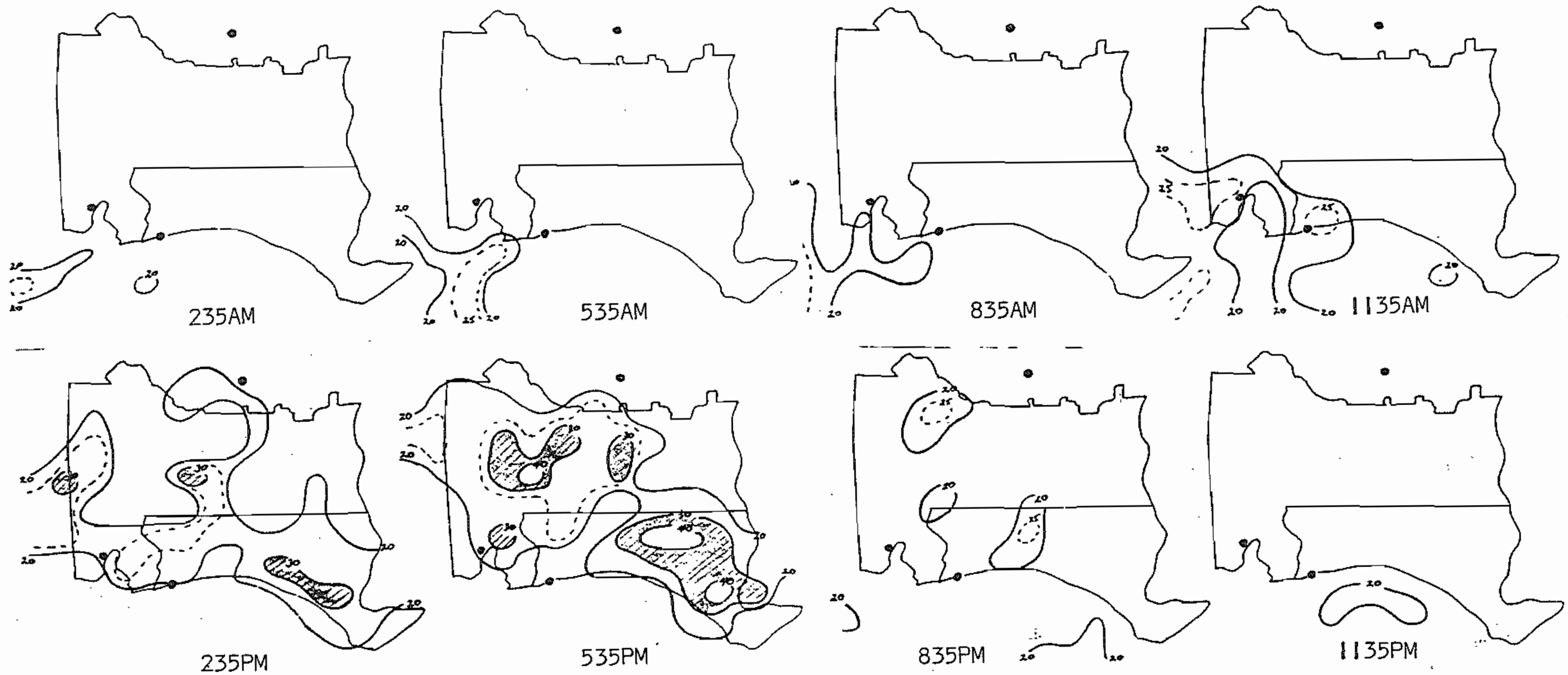
	Zone	Day (7A-7P)	Night (7P-7A)
FLA	1	29	10
	2	29	16
	3	30	11
	4	28	10
ALA	13	20	5
	14	25	9
	15	19	7
	16	22	13



ECHO FREQUENCY:
WESTERLY DAYS
All times CDT.

AVG AREAL COVERAGE (%)

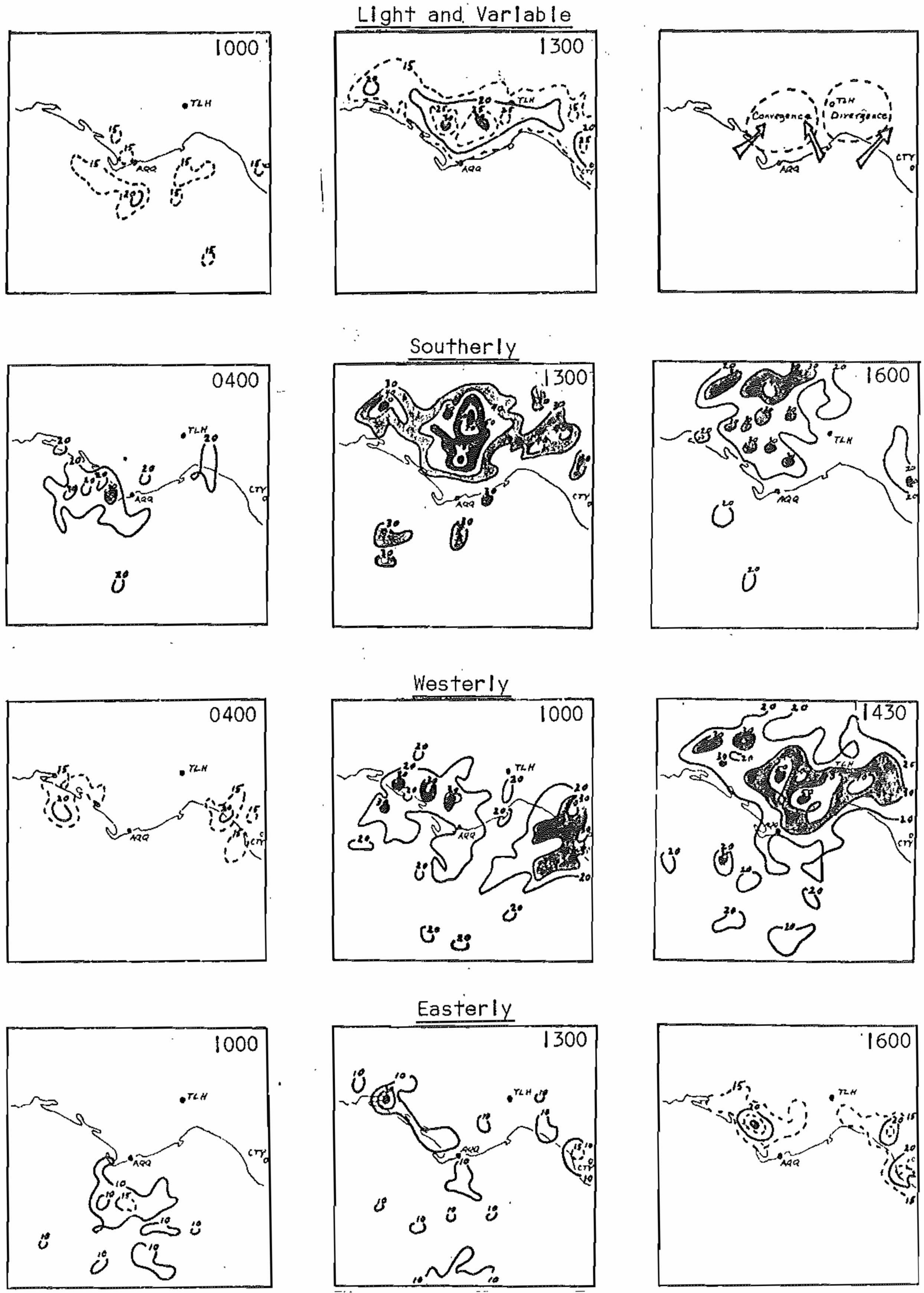
	Zone	Day (7A-7P)	Night (7P-7A)
FLA	1	39	24
	2	44	24
	3	34	20
	4	32	17
ALA	13	30	21
	14	29	19
	15	24	18
	16	39	22



AVG AREAL COVERAGE (%)

	Zone	Day (7A-7P)	Night (7P-7A)
FLA	1	28	7
	2	21	10
	3	23	4
	4	15	5
ALA	13	9	6
	14	19	8
	15	10	5
	16	27	9

ECHO FREQUENCY:
EASTERLY DAYS
All times CDT.



Radar echo frequency distribution (%) for indicated prevailing wind regimes (from Smith, 1970). All times CDT.